

**PROPAGATION AND FIRE TESTS CONDUCTED ON A
SECONDARY STEEL CONTAINER DESIGNED FOR
MOVEMENT OF CHEMICAL AGENT ARTILLERY PROJECTILES**

**DANIEL B. HILL
Ammunition Equipment Directorate
Tooele Army Depot, Utah**

**Presented at:
TWENTY-FOURTH DOD EXPLOSIVES SAFETY SEMINAR
Dept. Of Defense Explosives Safety Board
St. Louis, Missouri
28-30 August 1990**

ABSTRACT

A Secondary Steel Container (SSC) has been developed to hold two pallets of 8" projectiles or three pallets of 155mm projectiles for use in the movement of chemical agent munitions. To answer questions on the impact that the container might have on the maximum credible event from the detonation of one projectile in the pallets, propagation tests were conducted. Two fire cookoff tests were also conducted to evaluate the time that fire fighters would have to extinguish a fire involving SSCs in MILVANS subjected to a large fuel fire resulting from an accident.

Report Documentation Page				Form Approved OMB No. 0704-0188	
Public reporting burden for the collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington Headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to a penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number.					
1. REPORT DATE AUG 1990		2. REPORT TYPE		3. DATES COVERED 00-00-1990 to 00-00-1990	
4. TITLE AND SUBTITLE Propagation and Fire Tests Conducted on a Secondary Steel Container Designed for Movement of Chemical Agent Artillery Projectiles				5a. CONTRACT NUMBER	
				5b. GRANT NUMBER	
				5c. PROGRAM ELEMENT NUMBER	
6. AUTHOR(S)				5d. PROJECT NUMBER	
				5e. TASK NUMBER	
				5f. WORK UNIT NUMBER	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Tooele Army Depot, Ammunition Equipment Directorate, ,Tooele, UT, 84074				8. PERFORMING ORGANIZATION REPORT NUMBER	
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)				10. SPONSOR/MONITOR'S ACRONYM(S)	
				11. SPONSOR/MONITOR'S REPORT NUMBER(S)	
12. DISTRIBUTION/AVAILABILITY STATEMENT Approved for public release; distribution unlimited					
13. SUPPLEMENTARY NOTES See also ADA235006, Volume 2. Minutes of the Explosives Safety Seminar (24th) Held in St. Louis, MO on 28-30 August 1990.					
14. ABSTRACT					
15. SUBJECT TERMS					
16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT Same as Report (SAR)	18. NUMBER OF PAGES 28	19a. NAME OF RESPONSIBLE PERSON
a. REPORT unclassified	b. ABSTRACT unclassified	c. THIS PAGE unclassified			

**PROPAGATION AND FIRE TESTS CONDUCTED ON A
SECONDARY STEEL CONTAINER DESIGNED FOR
MOVEMENT OF CHEMICAL AGENT ARTILLERY PROJECTILES**

INTRODUCTION

In response to a requirement for retrograde movement of lethal chemical agent artillery projectiles from the Federal Republic of Germany, the Army developed a steel overpack container that will provide secondary containment of agent (in liquid or vapor state) that may leak from the projectiles during transport. The overpack is further designed such that several of them can be transported in a MILVAN shipping container. This paper describes two test programs conducted to evaluate: (1) the potential for propagation of detonation of projectiles within the overpack, thus affecting maximum credible event calculations; and (2) time to cookoff of projectiles, should the MILVAN be involved in an accident resulting in an engulfing fire, thus impacting fire response planning for the move.

The U.S. Army Defense Ammunition Center & School (USADACS), located at Savanna Army Depot Activity in Savanna, Illinois, designed the steel container which is now called the Secondary Steel Container (SSC). The container is designed to provide a vapor tight containment for explosively-loaded chemical ammunition in accordance with requirements of Amendment 25 to the International Maritime Dangerous Goods (IMDG) Code. The container will hold two pallets (six projectiles each) of 8 inch artillery projectiles, or three pallets (eight projectiles each) of 155mm projectiles.

At the request of a DA-level Chemical Retrograde Task Force, the Ammunition Equipment Directorate (AED) at Tooele Army Depot, Utah conducted several tests during the period 4 October 1989 through 1 March 1990. This paper is later divided into two sections for purpose of describing each test separately. The tests are reported in AED Test Reports 17-89¹ and 04-90².

Propagation Test Summary

The projectiles are normally stored and/or transported in standard wooden pallets, burstered and without fuze. In such configuration, the palletized projectiles are U.N. Hazard

¹ Hill, Daniel B., Tests to Determine Extent of Propagation or Damage When 8" or 155mm Chemical Agent Simulant Filled Projectile Detonates Within Standard Pallet and in Pallet Overpack, 19 October 1989

² Hill, Daniel B., Secondary Steel Container Fire Tests, 30 March 1990

Class/Division 1.2 non-mass detonating munitions, indicating that in event of accidental detonation of one projectile within the pallet, propagation to adjacent projectiles will not occur. With development of the overpack container, it became necessary to determine if the containment might cause detonation of additional projectiles, thereby changing the hazard classification. The data was desired specifically for 8" M426 GB or VX projectiles and 155mm M121A1 GB or VX projectiles.

Tests were conducted on the two different sizes of projectiles during the period 4-10 October 1989 to determine if propagation would occur within the overpack container. An additional objective was to determine how many projectiles might be expected to leak their liquid agent fill. The tests were conducted using a liquid agent simulant. Three detonation tests were conducted for each size projectile:

- °Single 8" projectile was detonated
- °Donor in 2 std pallets of 8" projectiles was detonated
- °Donor in 2 pallets of 8" projectiles within overpack was detonated

- °Single 155mm projectile was detonated
- °Donor in 3 std pallets of 155mm projectiles was detonated
- °Donor in 3 pallets of 155mm projectiles within overpack was detonated

No propagation occurred in any of the tests. In the overpacked 8" projectile test, four projectiles incurred sufficient damage to leak their liquid fill. In the overpacked 155mm test, seven projectiles leaked.

Fire Test Summary

A movement planning scenario envisions an accident resulting in a large fuel fire that engulfs a MILVAN loaded with SSC which are filled with projectiles. Assuming that projectiles will eventually begin to cookoff in such a fire, it was desired to know how much time a fire response team may have to fight the fire before the first projectile detonates; therefore, tests were conducted on 6 February and 1 March 1990 which subjected SSCs to fuel fires. The test SSC were each loaded with three explosive filled 155mm projectiles and 21 inert projectiles. All were filled with ethylene glycol/water mix to simulate chemical agent. The SSCs were placed into CONEX containers to represent a MILVAN shipping container. Each assembly was suspended over a pan of fuel which was then ignited.

In the first test, the fire lasted approximately 44 minutes and, although no projectiles cooked off or detonated, the test appeared to demonstrate that a reasonable amount of time would be available to safely fight the fire. In the second test, one projectile burster cooked off in one hour ten minutes and a

second burster cooked off in one hour seventeen minutes. The third live projectile did not function.

DESCRIPTION OF SSC

The SSC is a front-loading, skid-mounted steel container with the following approximate overall dimensions: 33½" wide x 42½" long x 47½" high. See Figure 1. Its interior dimensions will accommodate two pallets of 8" projectiles or three pallets of 155mm projectiles, with appropriate wood blocking/bracing to prevent shifting of the pallets within the SSC.

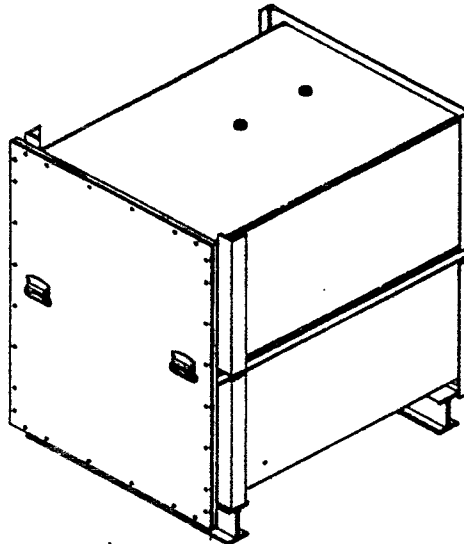


FIGURE 1. SECONDARY STEEL CONTAINER

The SSC is constructed essentially of 3/16" thick medium carbon steel plate, forming a box that is mounted on two standard 5" flange beams that provide side access for forklift. The front of the container is a 5/8" thick flange plate to which a 1/4" thick closure door is bolted with 28 3/8" socket head capscrews that thread into the flange plate. A 3/16" thick butyl rubber gasket is glued to the closure door and provides the vapor-tight seal for the container. The closure door has two handles welded to it for manual handling. Threaded fittings at the top of the container permit attachment of an air monitoring device and a valve to allow air to be drawn into the container while monitoring. The SSC weighs approximately 800 lbs.

PROPAGATION TESTS

These tests were conducted in two phases for each of the two test munitions. Phase 1 was a baseline test in which two 8" or three 155mm standard pallets were placed side by side and a donor round in one pallet was detonated to obtain baseline damage and pressure data to be used for comparison with data from Phase 2. In Phase 2, two 8" or three 155mm standard pallets were placed within the Secondary Steel Container and a donor round in one pallet was detonated to assess any propagation effect caused by the SSC.

Prior to each Phase 1 test, a single round (for each size munition) was detonated to obtain pressure baseline data for comparison with Phase 1 data.

Objectives of the tests included:

1. Obtain "baseline" data for projectiles in standard pallets, to include measurement of blast pressure (to aid in determining if explosive propagation occurred), visual assessment of damage to other rounds within the donor pallet, and visual assessment of damage to rounds within acceptor pallets; specifically to determine the number of (and which) projectiles suffered sufficient damage to release simulant.
2. Determine if Secondary Steel Container affected or altered the results achieved in Phase 1 tests.
3. Determine fragment dispersion.

Blast pressures were determined by measuring peak positive incident overpressures with low-impedance piezoelectric pressure transducers placed at ground surface along two air blast instrumentation lines at 90 degrees to each other. In all tests, the donor round was placed at the intersection of these two blast lines. A 1½" thick steel witness plate provided a base for all tests. The donor round was initiated by an Exploding Bridgewire (EBW) firing circuit from a control center approximately 700 ft. away. High-speed cameras and real-time video documented the tests.

Munitions Preparation

The chemical agent version of the 8" projectile is the M426. The high-explosive version is the M106. M106 projectiles modified to the M426 configuration were used for these tests. The modified M106 was assembled with the M83 burster, which contains 7 lbs of composition B4; the supplementary charge containing 0.30 lbs of TNT; the appropriate cardboard spacer and support; and a lifting plug. The projectile cavity was filled

with 14.5 lbs of ethylene glycol/water (50/50 wt) to simulate the density property of chemical agent GB. Assembled and filled projectile weight is approximately 195 lbs. Palletized weight (6 rds/pallet) was approximately 1253 lbs.

155mm projectiles that had been modified from the M107 HE configuration to M121A1 chemical configuration were also used for these tests. The modified M107 was assembled with the M71 burster, which contains 2.45 lbs of composition B4; the supplementary charge containing 0.30 lbs of TNT; the appropriate cardboard spacer and steel support cup; and a lifting plug. The projectile cavity was filled with 6.5 lbs of liquid simulant. Assembled and filled projectile weight was approximately 99 lbs. Palletized weight (8 rds/pallet) was approximately 831 lbs.

All components were painted to assist identification in fragment collection after the tests. The 8" projectiles and all their components were painted one color while the 155mm were painted a distinctively different color. The donor projectile for each test was configured as follows:

1. The detector-type lifting plug was removed and a 1/8" hole drilled to accept an ionization probe. The detection screw was removed so the EBW detonator could be inserted into the approximately 36 grams of composition C4 that was packed into the lifting plug cavity.
2. The cardboard spacers were packed with composition C4 (approx 66 gm in the 8", 49 gm in the 155mm). The spacer, w/C4, was then emplaced atop the supplementary charge in the projectile.

SSC Preparation

The SSC for each test were painted different colors and were painted differently from the projectiles. After installation of the pallets of projectiles into the SSC, wood blocking and bracing was installed to preclude shifting or moving of the pallets within the SSC.

Test Setup

In both single projectile tests, the projectile was elevated above the witness plate, using wooden blocks, to a height approximating the elevation of the palletized projectiles within the SSC. In both Phase 1 tests, the pallets of projectiles were also elevated above the witness plate.

In the Phase 2 tests, the SSC, with projectiles and wood bracing already installed, were positioned in location at the test site. The EBW detonator was then inserted through the inspection hole, and the ionization probe inserted through the specially-drilled hole into the composition C4 in the lifting

plug. The electrical wires were fed through the sampling hole in the top of the SSC. The SSC cover plate was then bolted in place, following specified torquing instructions.

Prior to each test, a spherical charge of approximately one lb. of composition C4 was detonated to validate the pressure transducer array. A fragment search was conducted at the conclusion of the tests. Fragments found in each 200 ft. cell within each of three 5° search sectors were reported as were major pieces of debris or unexploded components found outside the search sectors.

Results

8" Projectile Tests

Single Projectile Baseline Test-Pressure data is given in Table 1. Fragment dispersion for within and outside the search sectors was plotted and no fragments were found beyond 600 ft. from the detonation.

Standard Pallet Baseline Test-Pressure data is given in Table 1. Although no propagation occurred and all explosive components from acceptors were recovered, the damage was significantly more widespread in this test than was seen later in the overpack test. Five M83 bursters and eight supplementary charges were ejected from their projectiles; some as far away as 600 ft. One projectile was thrown 400 ft. Eight projectiles leaked their liquid fill.

Overpacked Pallet Test-Pressure data is given in Table 1. No propagation occurred and all explosive components from acceptors (two supplementary charges) were recovered. Four projectiles leaked their liquid fill. Two leaked significantly from around their burster cases; these were thrown 200 ft. Two were seepage-type leakers from around the joint between fuze adapter and projectile body. One was thrown 75 ft. and the other was thrown 50 ft. Deformation around the projectile nose caused the burster case press fit to break loose, allowing the liquid to leak. Damage to projectiles was not nearly as severe as was seen in the pallet baseline test; i.e., no projectile bodies were cracked although some were severely dented, only two projectiles lost their fuze adapters, and all others even retained their lifting plugs. The SSC split open at the rear and top joints with the top and the door being blown completely off.

TABLE 1-BLAST PRESSURE DATA FOR 8" PROJECTILE TESTS

TEST	BLAST LINE	TRANSDUCER STATION	R ft.	P _{so} psi	t _a ms	t _o ms
SINGLE ROUND	A	1	15	15.73	83.6	31.6
		2	22	11.73	131.4	34.6
		3	40	7.64	288.0	7.96
	B	4	15	13.61	81.4	32.4
		5	22	10.96	133.2	32.6
		6	40	5.73	244.0	14.6
STANDARD PALLET	A	1	15	11.92	86.08	34.4
		2	22	5.78	142.8	42.2
		3	40	3.34	297.6	52.5
	B	4	15	11.41	83.0	33.2
		5	22	7.68	137.6	39.8
		6	40	3.94	290.8	86.0
OVERPACKED PALLET	A	1	15	5.44	140.4	51.8
		2	22	3.62	198.0	46.8
		3	40	2.28	352.6	49.2
	B	4	15	4.89	141.4	59.5
		5	22	3.91	200.6	86.2
		6	40	2.00	358.4	72.4

R = Horizontal distance from center of donor round to transducer station, feet

P_{so} = Peak positive incident pressure, pounds per square inch

t_a = Time of arrival of blast wave, milliseconds

t_o = Duration of positive phase, milliseconds

155mm Projectile Tests

Single Projectile Baseline Test-Pressure data is given in Table 2. Fragment dispersion for within and outside the search sectors was plotted and no fragments were found beyond 600 ft. from the detonation. The blast pressure at transducer 5 in Blast Line B is abnormally low, however, it's likely that some ground-level obstruction (rock or dirt mound) deflected the blast wave.

Standard Pallet Baseline Test-Pressure data is given in Table 2. No propagation occurred and no explosive components were released or ejected from any acceptors. Transducer 5 recorded an abnormally high pressure which is unexplained. There was no extensive damage to any of the acceptors; i.e., none were

broken or cracked, however seven rounds leaked their liquid fill. One projectile was thrown approximately 600 ft. The leakage results from deformation of the projectile nose causing the burster case press-fit to break loose.

Overpacked Pallet Test-Pressure data is given in Table 2. No propagation occurred and no explosive components were ejected from acceptors. Blast pressure readings appear normal. Seven projectiles were leakers. Two leakers were thrown 175 ft., one 150 ft., one 100 ft., and three were thrown 50 ft. All leakers were seepage-type leakers with no significant loss of liquid; and no projectiles were severely damaged. The SSC did not blow apart as was seen in the 8" test. The door blew off, landing approximately 500 ft. away.

TABLE 2-BLAST PRESSURE DATA FOR 155mm PROJECTILE TESTS

TEST	BLAST LINE	TRANSDUCER STATION	R ft.	P _{so} psi	t _a ms	t _o ms
SINGLE ROUND	A	1	15	8.42	96.0	2.4
		2	22	4.10	153.8	1.8
		3	40	2.34	313.8	38.0
	B	4	15	8.61	94.8	25.4
		5	22	1.78	173.6	16.4
		6	40	3.04	308.8	62.8
STANDARD PALLET	A	1	15	6.36	104.8	29.5
		2	22	3.31	163.6	26.0
		3	40	1.87	322.8	77.2
	B	4	15	6.20	103.2	28.4
		5	22	8.30	157.6	39.5
		6	40	1.71	322.0	36.0
OVERPACKED PALLET	A	1	15	2.71	135.4	43.4
		2	22	1.87	195.2	41.4
		3	40	0.76	352.8	48.0
	B	4	15	1.97	123.4	65.2
		5	22	1.49	189.4	71.5
		6	40	0.75	348.6	36.7

R = Horizontal distance from center of donor round to transducer station, feet

P_{so} = Peak positive incident pressure, pounds per square inch

t_a = Time of arrival of blast wave, milliseconds

t_o = Duration of positive phase, milliseconds

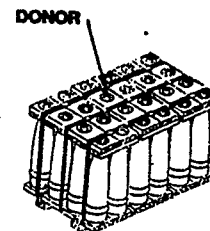
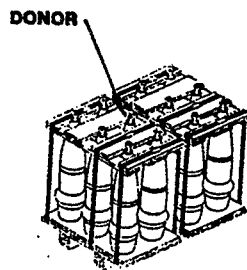
Conclusions

8" Projectile Tests-No significant anomalies were seen in the pressure data; i.e., the blast pressures seemed to decay normally as the pressure wave expanded outward across the transducers. The measured pressures also decreased with each test as would be expected, given the confinement of surrounding projectiles and the container. The lesser damage to acceptor projectiles in the overpacked pallet test might be explained by the instantaneous increase in air volume in the container, caused by the donor detonation, creating an air cushion between projectiles which minimized mechanical damage to them. The SSC also contained fragments, resulting in fewer being dispersed than seen in the standard pallet test.

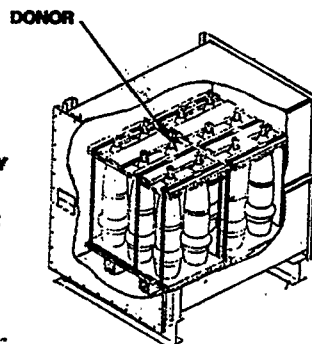
155mm Projectile Tests-With exception of anomalous readings at transducer 5 in the standard pallet and the overpacked pallet tests, the blast pressures appeared normal. As described above, mechanical damage to projectiles was minimal, and there was very little fragmentation.

The following five pages of photos illustrate the test setups and results. Discussion of the Fire Tests continues after the photos.

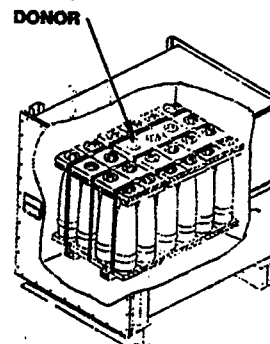
**PHASE 1
STANDARD PALLET**



**PHASE 2
SECONDARY
STEEL
CONTAINER**

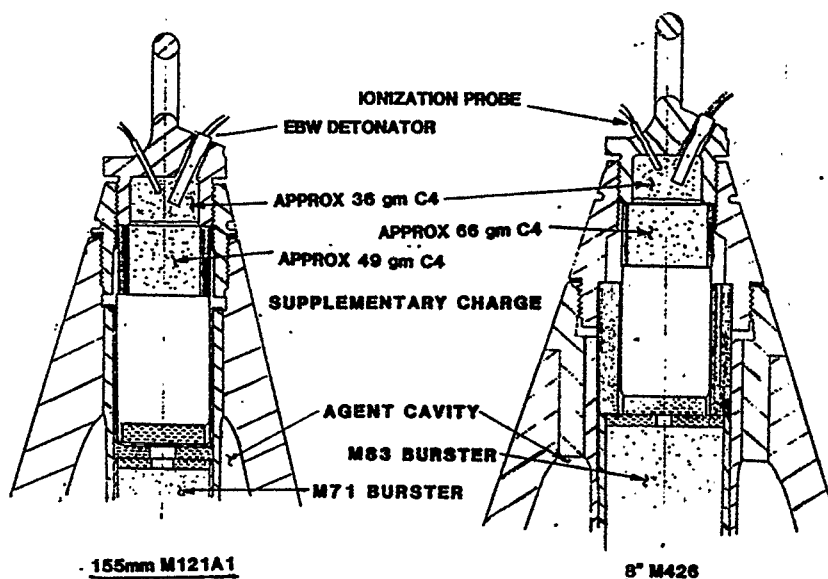


8" PROJECTILE M426

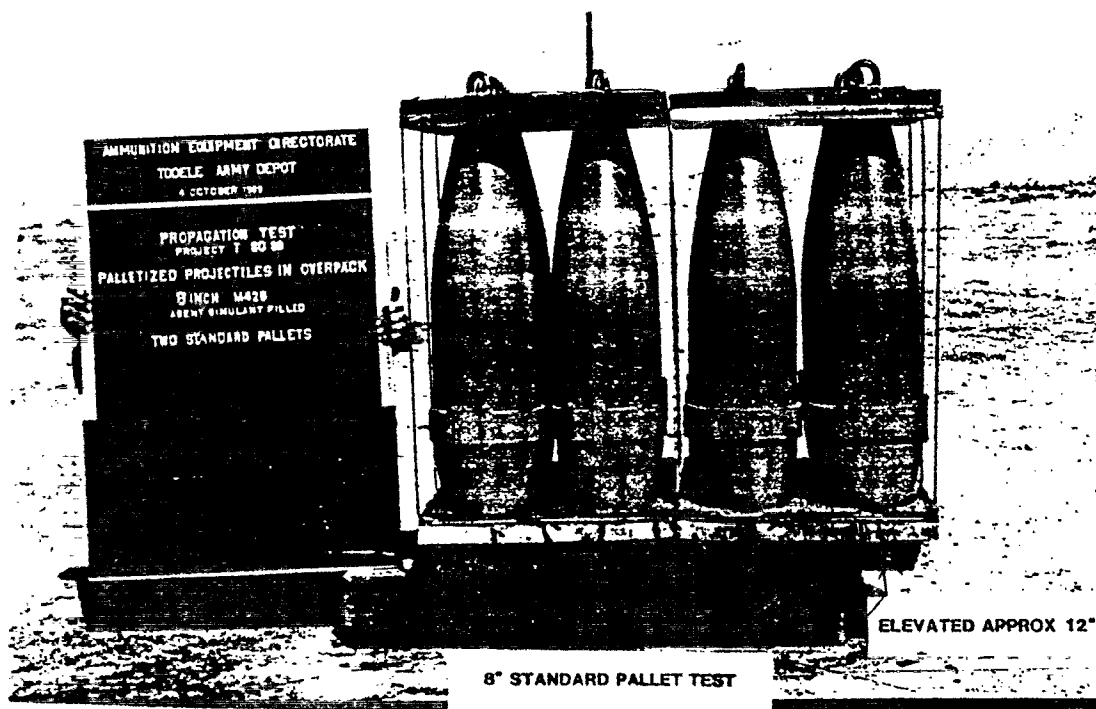
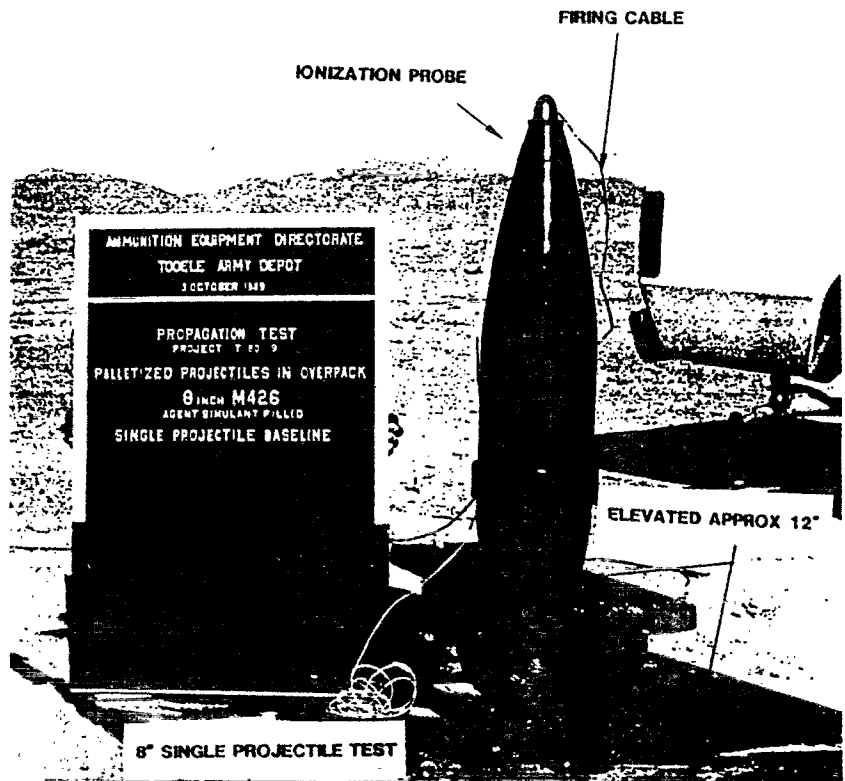


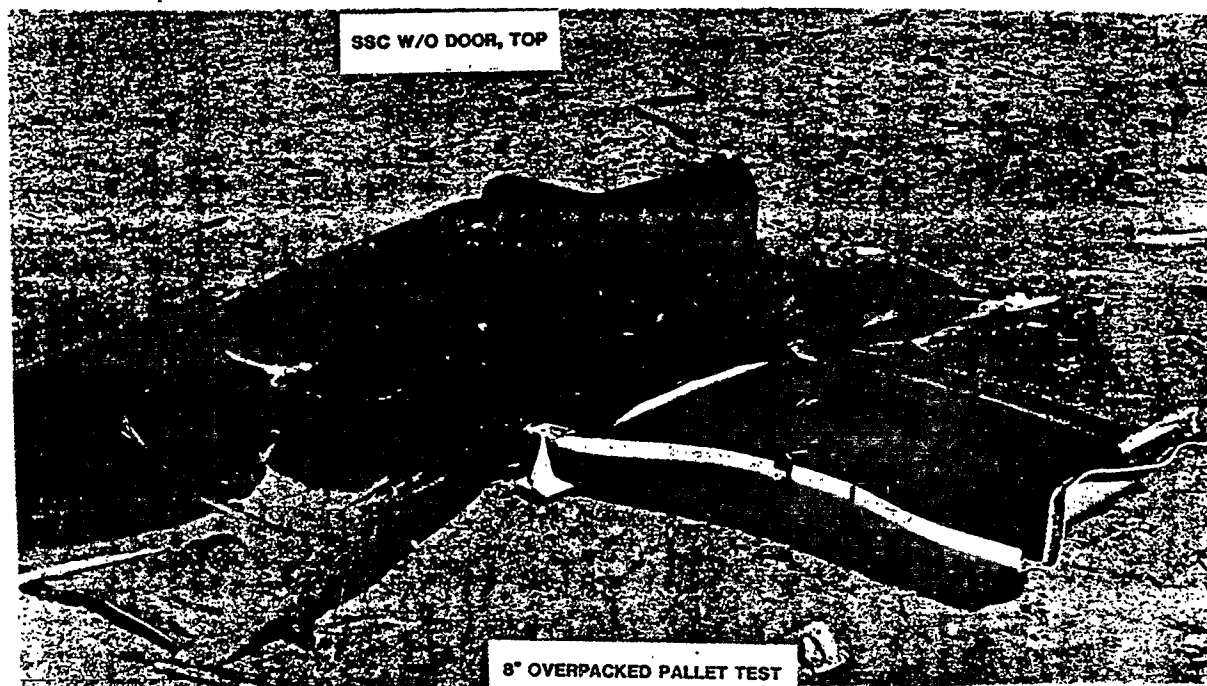
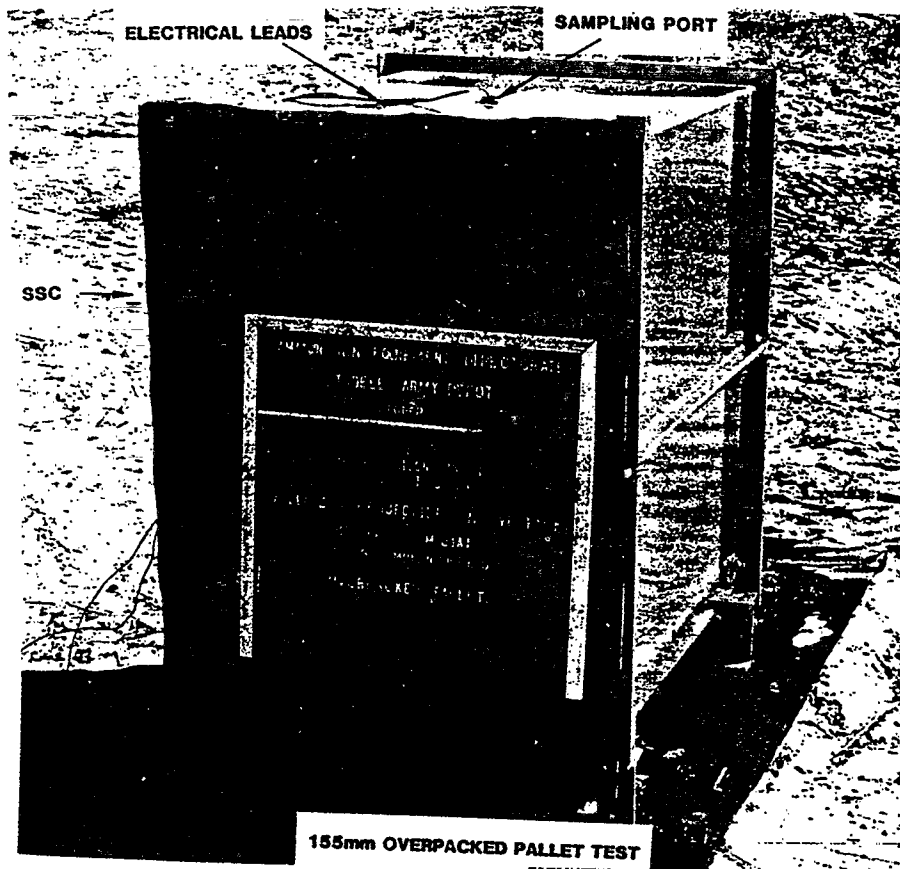
155mm PROJECTILE M121A1

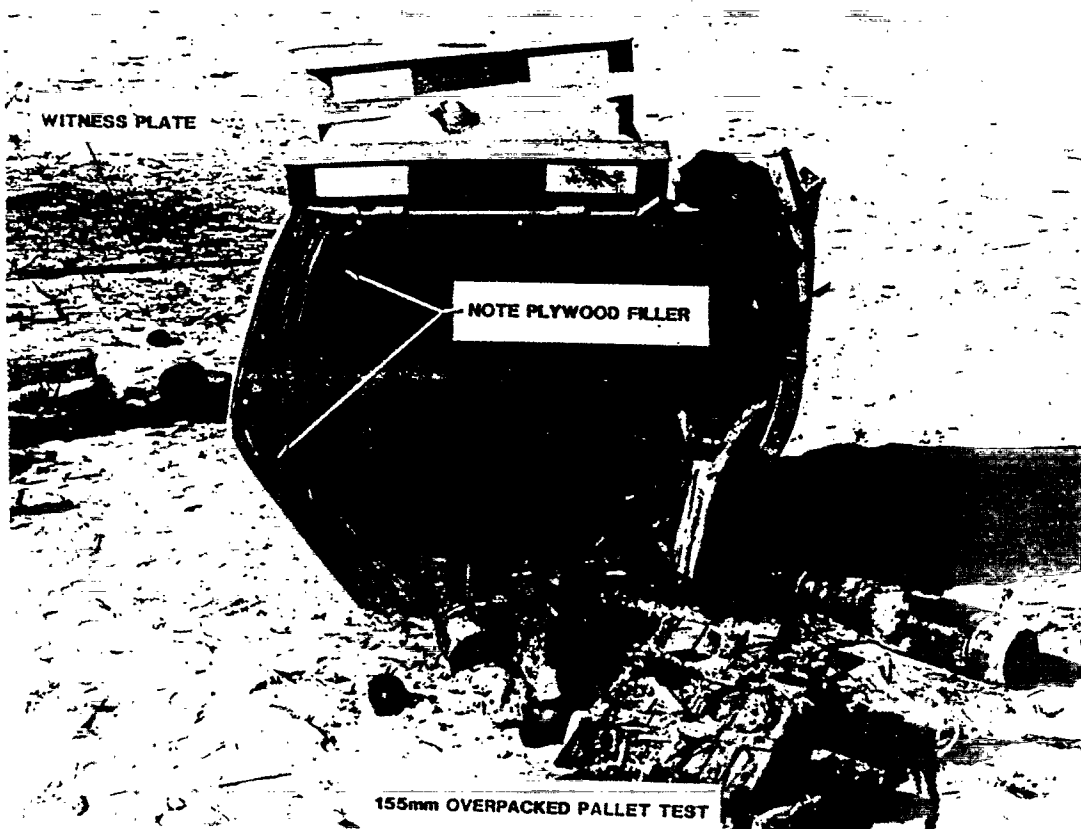
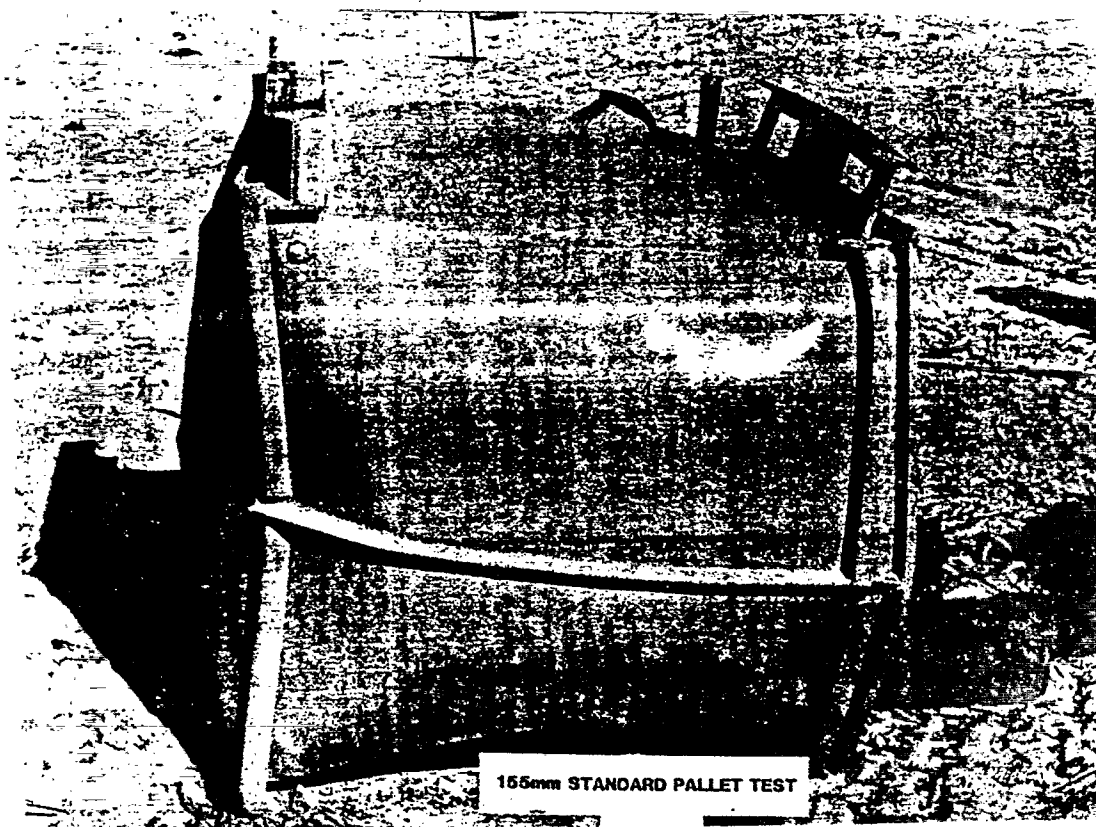
TEST CONFIGURATIONS

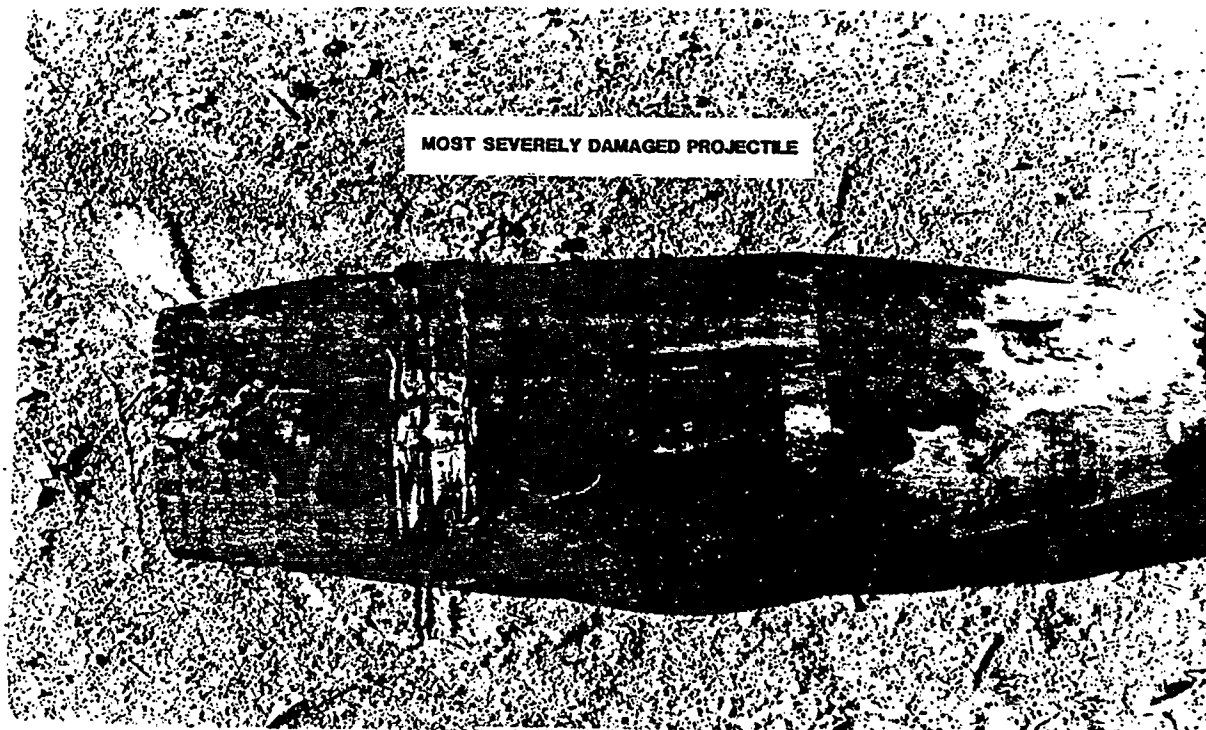
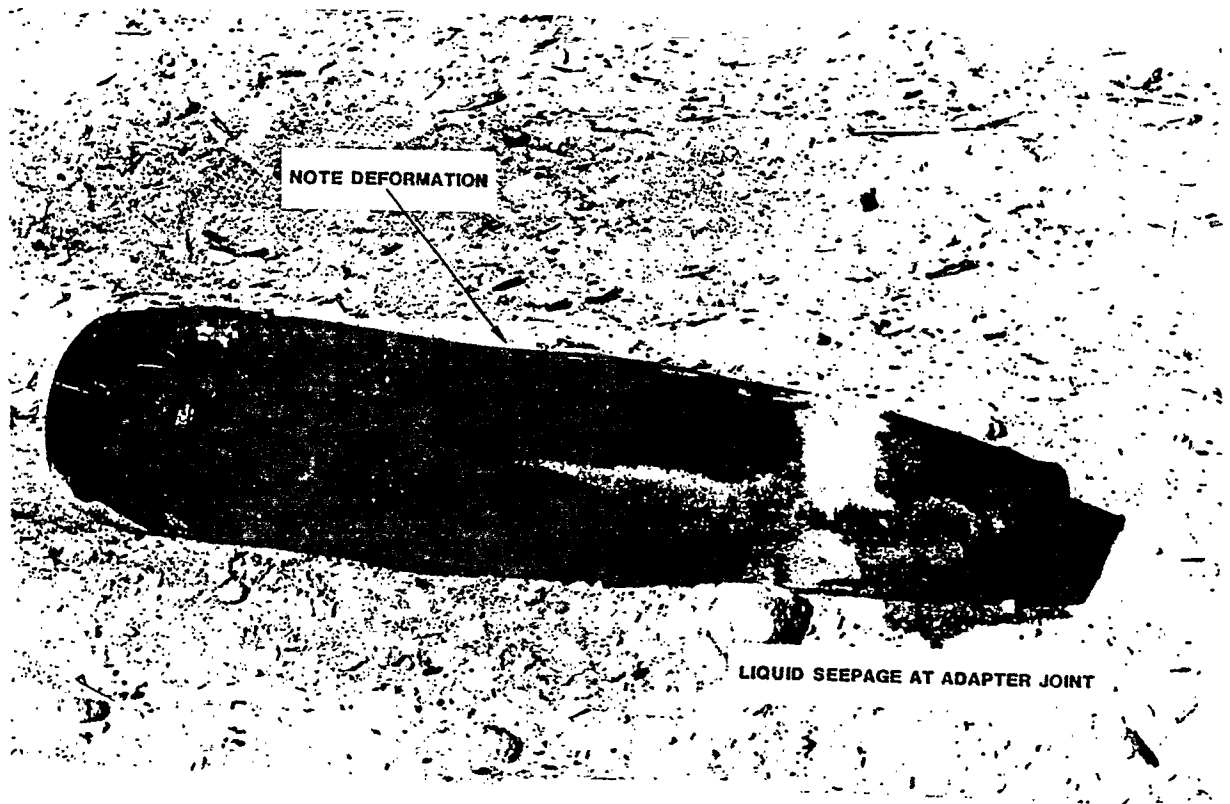


PREPARATION OF DONOR PROJECTILE









FIRE TESTS

Two tests were conducted, on 6 February and 1 March 1990, which subjected SSCs to fuel fires with the objective of determining length of time to "cookoff" of explosively loaded 155mm projectiles within the container. The test SSC were each loaded with three explosive filled 155mm projectiles and 21 inert projectiles. All were filled with ethylene glycol/water to simulate chemical agent. The SSCs were placed into CONEX containers which represented a MILVAN shipping container. Each assembly was suspended over a pan of fuel (first test JP-5, second test diesel fuel) which was then ignited. Thermocouples recorded time/temperature histories, including the temperatures at the tops of the three bursters in the live projectiles.

In actual loading, the SSC are intended to be installed in the MILVAN with the SSC door facing outward, toward the MILVAN sidewall. For each of these tests, a fixture was fabricated to closely approximate the configuration of one SSC at the rear corner of a MILVAN.

The 155mm M121A1 (with liquid agent simulant) was selected as the test munition instead of the 8" because of its' thinner wall and the fact that, within the SSC, it is slightly closer to the container wall, suggesting shorter time to cook-off. Three pallets of projectiles (24 total) were placed into the SSC. Three projectiles were explosively loaded with a composition B-filled M71 burster. Two outside projectiles were approximately 3/8" from the SSC sidewall (one was adjacent to a plywood sheet which was fill material placed between the SSC door and the pallet of projectiles). The other live projectile was placed near the center of the SSC. All wood blocking/bracing specified by the SSC loading drawing was used (plywood sheets were at the side opposite the live projectiles).

The SSC was then placed into a corner of a standard Conex shipping container (representative of a MILVAN container). The door side of the SSC was approximately 4" from one wall of the container. The positioning was determined by wooden side blocking required by the MILVAN loading drawing. One side wall of the SSC (adjacent to two of the live projectiles) was approximately 24" from the other Conex wall. The Conex corner was then partitioned with floor to ceiling panels against the back and other side walls of the SSC, creating an enclosure for the SSC with an air volume roughly equivalent to the unit volume that will exist in the MILVAN, which is approximately 69 ft³ of free air. The partition panels were insulated to prevent loss of heat from within the enclosure and to prevent entry of heat into the SSC through two walls (i.e., suggestive of surrounding SSC). The floor of the enclosure was lined with hardwood material to simulate the MILVAN flooring.

All projectiles were filled with an ethylene glycol/water mix to simulate liquid agent. Three projectiles were assembled with an explosive burster and a supplementary charge. The others had a plaster of paris-filled simulant burster and supplementary charge. The projectiles were appropriately palletized in wooden pallets and banded.

The corner of the Conex assembly was positioned above a burn tray filled with fuel. For the first test, the tray was initially filled with approximately 220 gallons of JP-5 fuel. Some literature indicated a burn rate of 0.1 in/min for JP-5 fuel. Using this rate, it was anticipated that 8.5" fuel depth should permit 85 minutes burn time. For the second test, the tray was filled with 275 gallons of diesel fuel. As a precaution against spilling fuel on the ground in event the burn tray was punctured by a detonation of the projectile(s), the burn tray was positioned within a larger, thick-walled pan.

The fuel was ignited by emplacing a small combustible container of gasoline in the fuel and igniting the gasoline with an M206 Countermeasure Flare which was ignited by electric squib.

Instrumentation for both tests consisted of several chromel/alumel thermocouples located throughout the Conex and the SSC. Thermocouples were also attached to the live projectiles. The thermocouple data was collected by a Fluke Datalogger. The tests were documented by video.

Results

Test One

At the start of the test, the ambient temperature was 42° F and the wind was blowing at 13 knots, impacting on the test fixture side adjacent to the SSC door. Subsequent readings were 7 knots, from the same direction. The temperature remained constant throughout the test, dropping only to 41° F at the end.

The fire burned approximately 44 minutes, significantly less time than expected because of the wind. Although the flames reached to the top of the Conex container, the wind generally swept the flames away from one side, affecting heat transfer through that side and through the SSC door. The measured flame temperature averaged 1300-1500° F. Note that the flame temperature was measured by a thermocouple inserted into the flame at one corner of the fuel pan and its readings fluctuated widely because the flame was affected by the wind.

No detonation occurred. Burstors 1, 2 & 3 reached maximum temperatures of 220, 180 & 200° F, respectively; but at

approximately 1 hour 9 minutes after the fire died out, having continued to absorb heat from surrounding projectile bodies and the SSC. Table 3 gives the burster temperatures at the time the fire died down and the apparent average rate of temperature climb at that time.

TABLE 3-BURSTER TEMPERATURES
(at time fire died down)

<u>BURSTER NO.</u>	<u>°F</u>	<u>°C</u>	<u>RATE OF TEMP CLIMB, °F/min</u>
1	122.9	50.5	9°/min
2	91.1	32.8	3°/min
3	132.4	55.8	3°/min

Burster 3 exhibited sign of near melting in that it was lightly stuck to the bottom of the support cup. The TNT supplementary charge atop Burster 2 experienced some melting; i.e., the light gage aluminum closure disc was completely melted away and the explosive was melted down approximately 1/8". Burster 1 wasn't examined because the projectile couldn't be disassembled. Liquid temperatures in Projectiles 1 & 3 were essentially the same as the respective bursters and exhibited the same temperature rise rates. The liquid temperature data for Projectile 2 was lost due to thermocouple malfunction. Much of the projectile body temperature data was also lost due to malfunctioning thermocouples; however, maximum temperatures, recorded well after the fire died out, were 215° F on the exterior of Projectile 3, and 187° F on the base of Projectile 1.

Unfortunately, the thermocouple measuring the air temperature inside the SSC failed and no data was obtained. The thermocouples measuring door and wall exterior temperatures recorded maximums of 493 and 921° f, respectively. These temperatures were measured just before the fire died down and were in a relatively steep rate of climb. The floor temperature (inside the SSC) was at about 225° F when the fire died but continued to climb to a peak of 665° F 33-34 minutes later. The interior sidewall temperature peaked at 637° F about halfway through the burn; and the door interior wall temperature reached 371° F. There was some charring of the wood blocking/bracing but no significant combustion. The butyl rubber gasket was largely melted away although there were segments that were relatively intact.

Air temperatures inside the Conex were measured at several locations. Air temperatures rose very quickly to 400° F, within about 4 minutes after ignition. Air Temperature 1 reached 1000° F in approximately 27 minutes and Air Temperature 2 reached 1000° F in about 41 minutes, shortly before the fire died out. The floor temperature was measured at the surface of the wood floor, beneath the SSC. The temperature curve exhibited an abrupt change in rise rate at about 12-13 minutes after ignition and the

wood floor could be seen burning at about 20 minutes. The wood floor was eventually totally consumed by fire.

Test Two

The second test was conducted in the afternoon of 1 March. The ambient temperature was 51° F and there was just a slight breeze blowing, 0-5 knots from the west. The temperature remained relatively constant throughout the test, dropping to 48° F by end of test. A light rain fell during much of the test. Although the breeze was light, the fire did not fully engulf one side of the test fixture as completely as desired. The flame temperature averaged 1100-1300° F.

At one hour ten minutes after ignition of the diesel fuel, just as the fire was starting to die down, a significant explosion occurred. Seven minutes later, at one hour seventeen minutes, a second, less devastating explosion occurred; and four minutes after that, at one hour twenty-one minutes, a flash, without sound, was seen on the TV monitors.

Upon subsequent inspection it was determined that only projectiles 2 and 3 had functioned. Projectile 3, located to the rear of the SSC, was the first to detonate. The flash seen on the TV monitor was probably caused by liquid fill venting from one of the projectiles, possibly from the unexploded projectile 1. None of the other projectiles were damaged at all. A steel burster case with empty aluminum burster tube within was found outside the earthen enclosure. It could not be determined with certainty which projectile it came from. The condition of the functioned projectiles (i.e., flared mouths, bodies not cracked or broken, nose closure missing), and the partially intact nature of the burster case suggest low-order detonation with the burster partially ejected. Video of the test reveals that the first detonation caused considerable damage to the test fixture, opening up the SSC and destroying the Conex.

A review of the video reveals that at about 25 minutes into the burn, the wood floor within the enclosure started burning and within a few minutes flame could be seen at the top corner of the Conex. The Conex floor and one air temperature curve reflect a drastic increase in temperature. SSC Temperatures show a quick rise in the SSC door temperatures (inside & outside), indicative of the fact that the flame engulfed that side of the Conex more than the other. SSC air temperature curve reflects a relatively normal rise as does the SSC exterior side wall temperature. The SSC floor and interior wall temperatures show a dramatic rise, initially corresponding to the rise in Conex floor temperature and then probably sustained by combustion of wood within the SSC. The Projectile #1 temperatures do not have a curve for the burster top, which was lost when dumping data from the datalogger to the computer; however, the liquid cavity temperature shows the same sharp rise seen in the subsequent curves for Projectiles 2 &

3. The exterior temperatures for the projectile bodies seem to follow the rise in the SSC floor temperature (resulting from combustion of wood within the SSC), which eventually catches up to the SSC air temperature. The interior temperatures, however, (liquid cavity and burster top) appear to have reached a critical temperature just prior to 2000 seconds where an exothermic degradation process begins in both the explosive and the ethylene glycol fill which drives those temperatures to 1500° F before leveling off. The reaction continues at a much slower rate until detonation.

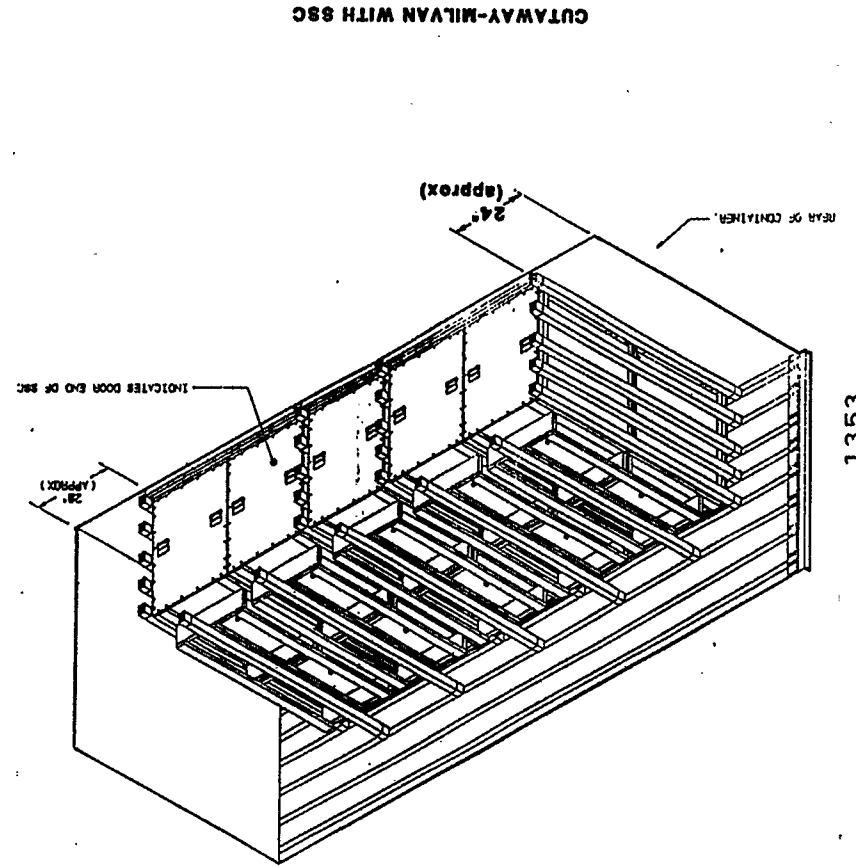
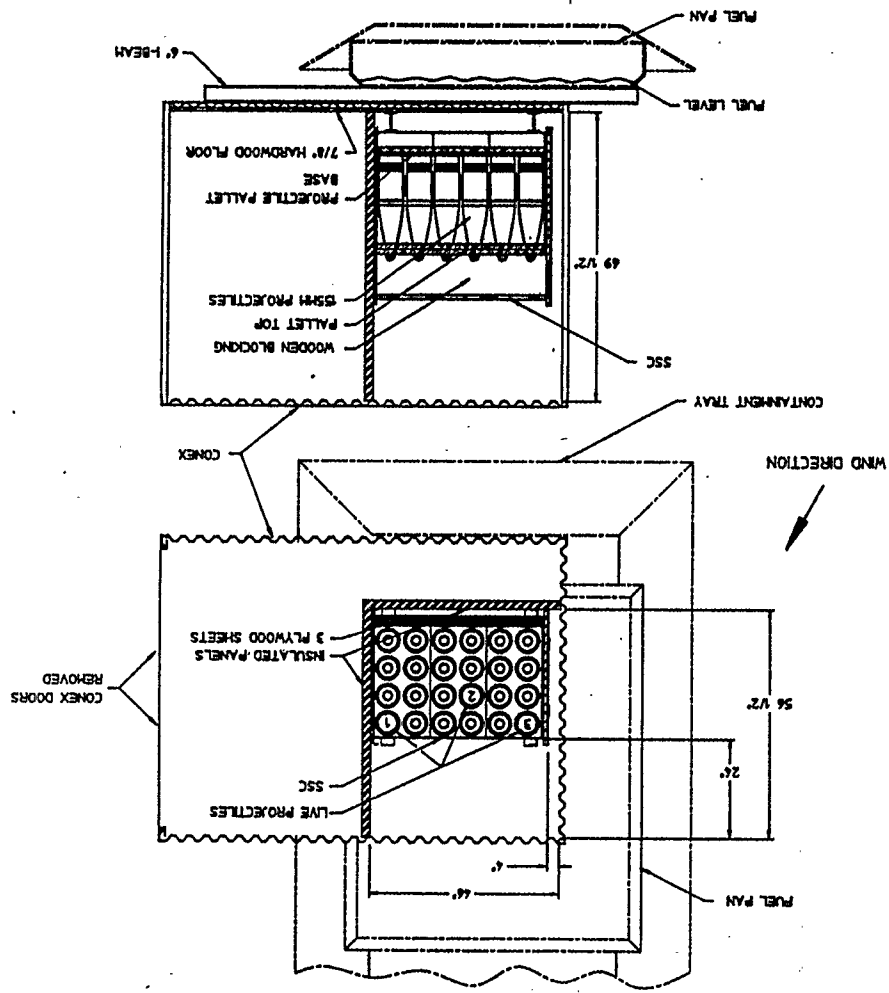
Conclusions

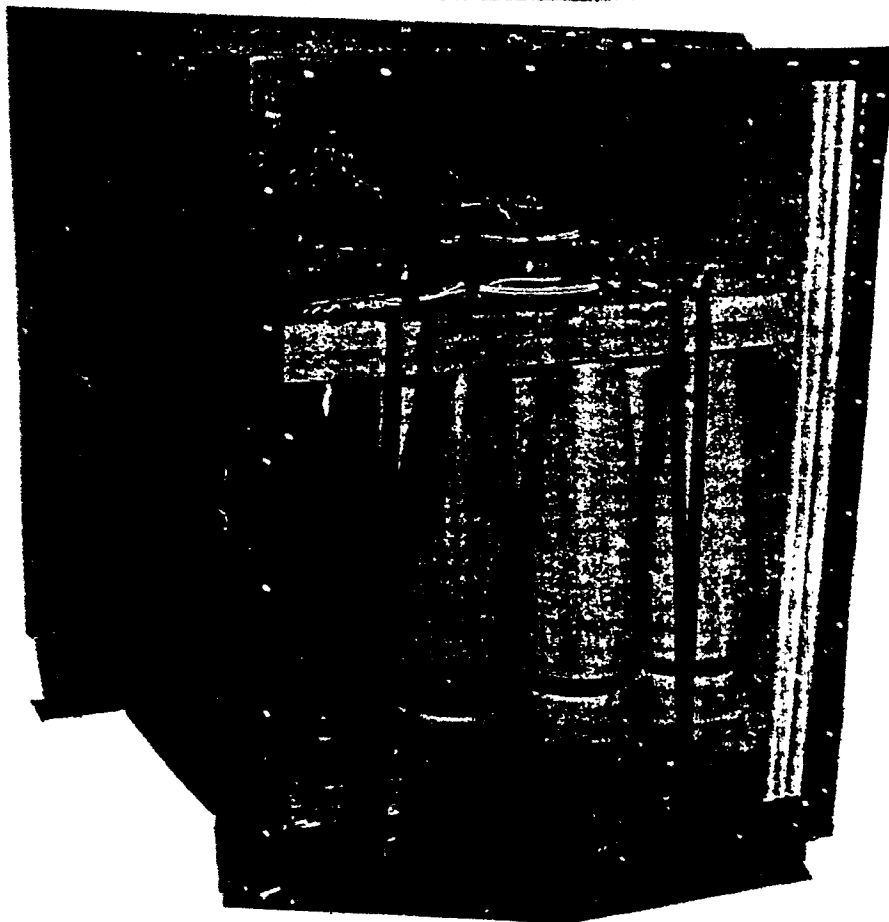
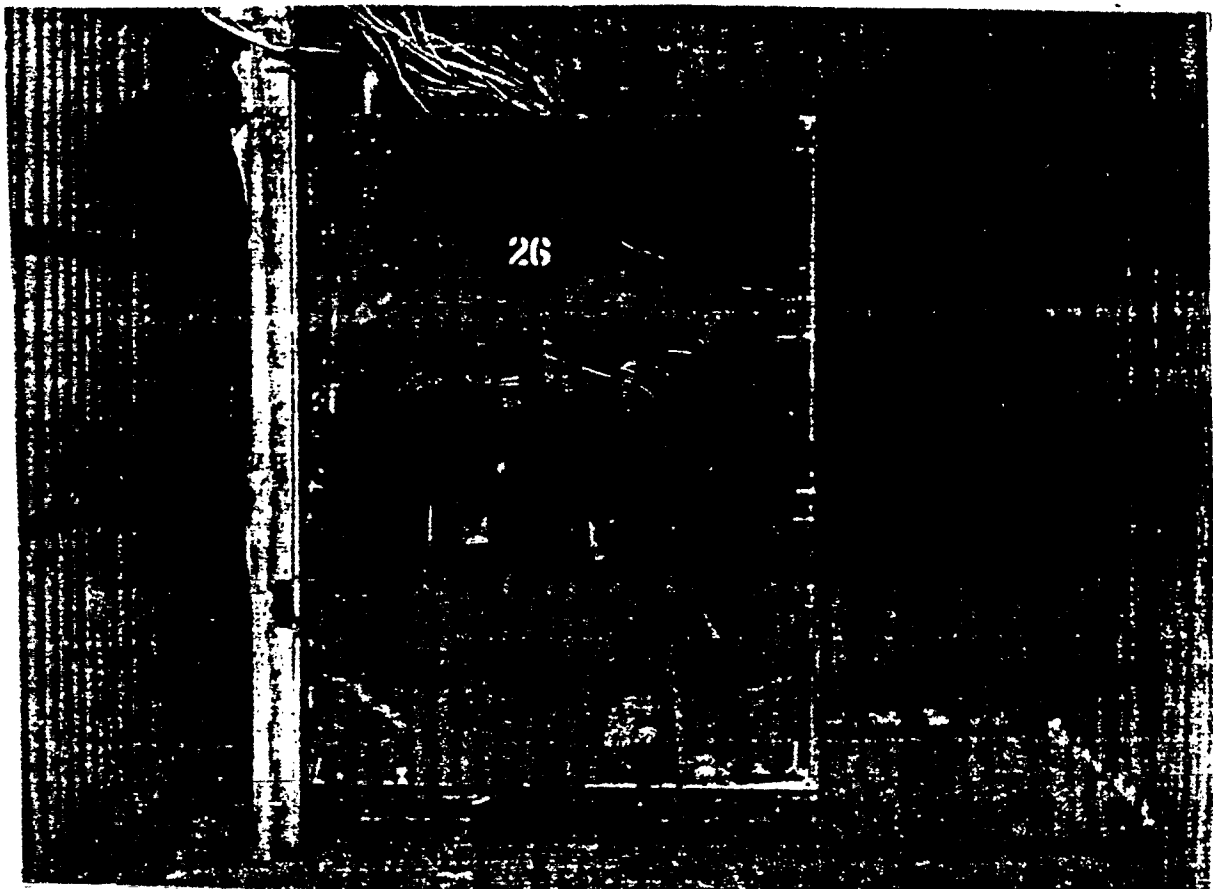
The two fire tests indicate that a reasonable amount of time is available to fire response personnel to fight a fire in the accident scenario described in the Introduction to this report, assuming that a response team can be on the scene within just a few minutes of ignition of such a fire. The SSC, with good structural integrity, appears to provide excellent protection for the projectiles from short-term exposure to fire, even under worst case conditions. Further, the blocking and bracing of the SSC within the MILVAN should generally ensure that the SSC will not be exposed directly to fire, providing the initial delay of heat transfer to the SSC.

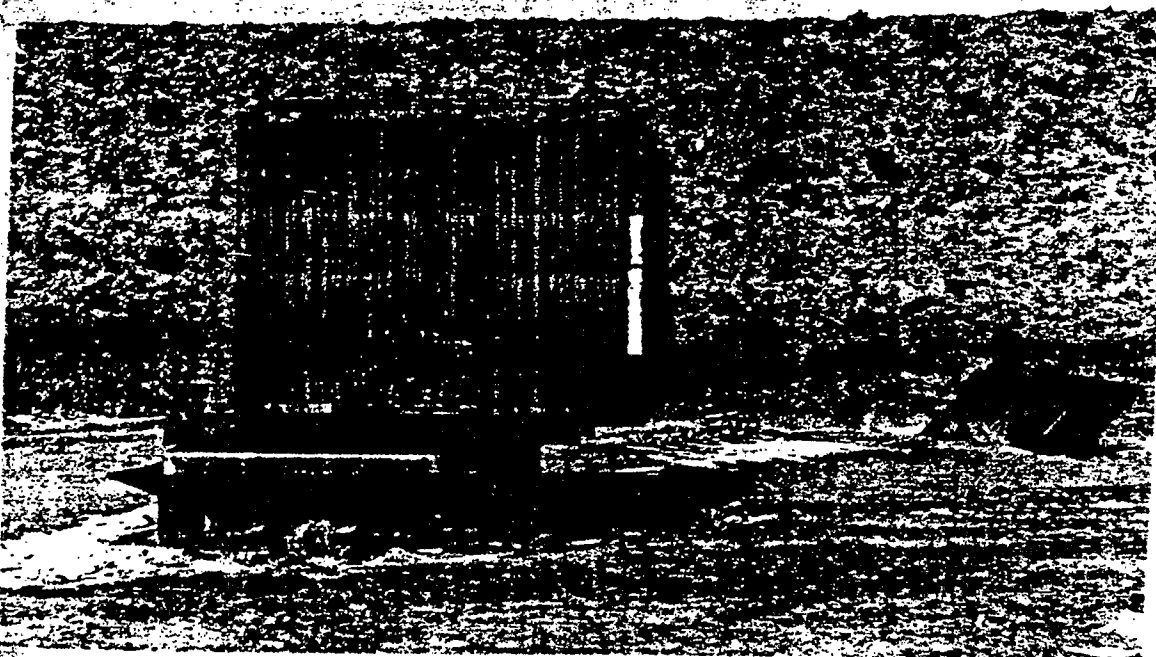
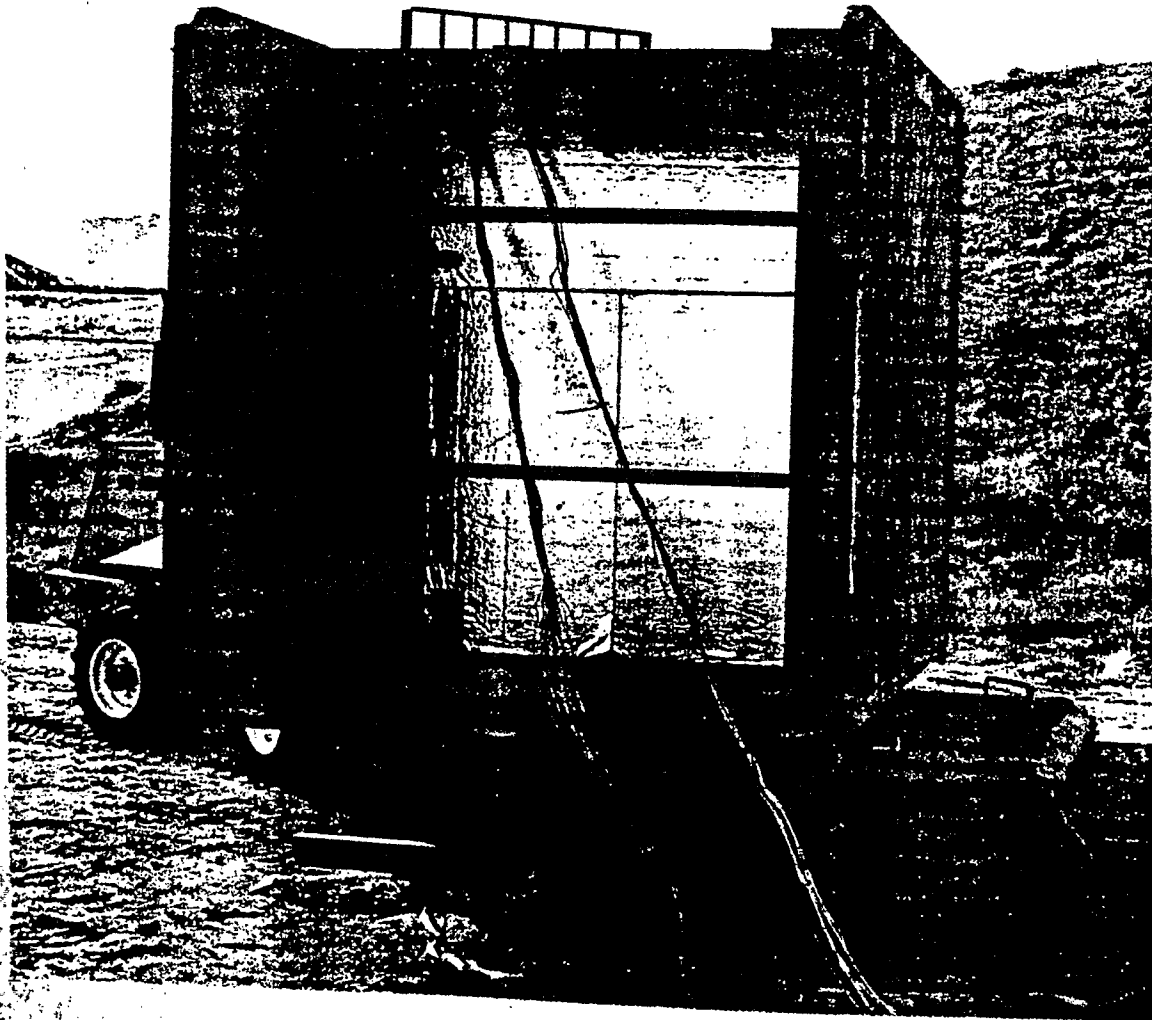
In both tests, the temperatures of the projectiles (both inside and outside) were near or below 150° F for the first 30 minutes, indicating relatively slow heat transfer through the SSC into the projectiles. Once the Conex wooden floor started burning at about 25 minutes in Test 2, however, temperatures within the SSC started to climb sharply. The Conex wooden floor in Test 1 rose to ignition temperature in about 15 minutes but did not actually begin to combust until 45-50 minutes after ignition of the fire. The conclusion here is that early combustion of the wooden floor in Test 2 was the driving mechanism that led to the detonations of the projectiles. Consideration may be given to treating the MILVAN wooden floors with fire retardant materials to gain further delay in combustion of the floor.

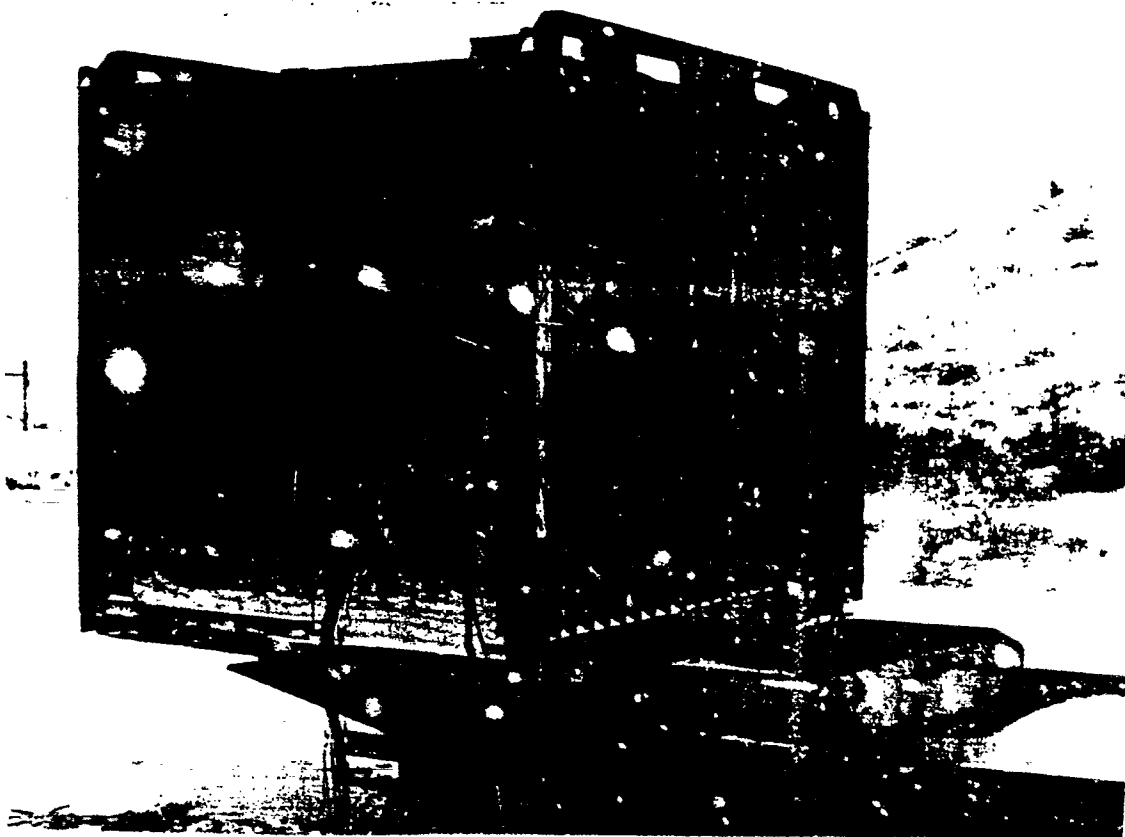
Thermocouple data from the two tests are not entirely consistent, largely because of the different wind conditions in each test which caused the fire to engulf the two critical sides of the Conex differently in each test. However, trends in rise rates in the two tests are reasonably consistent, especially for the first 25 minutes.

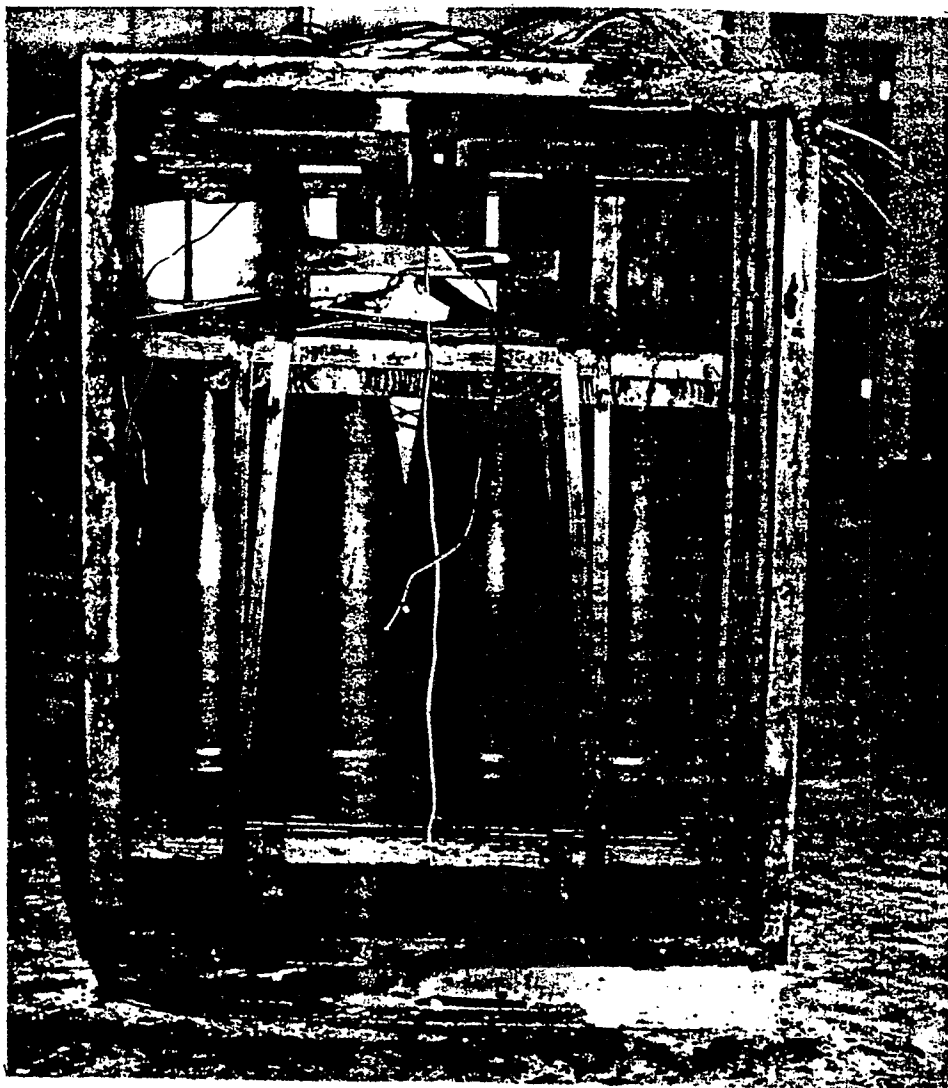
The next several pages illustrate setup and results for the two fire tests.



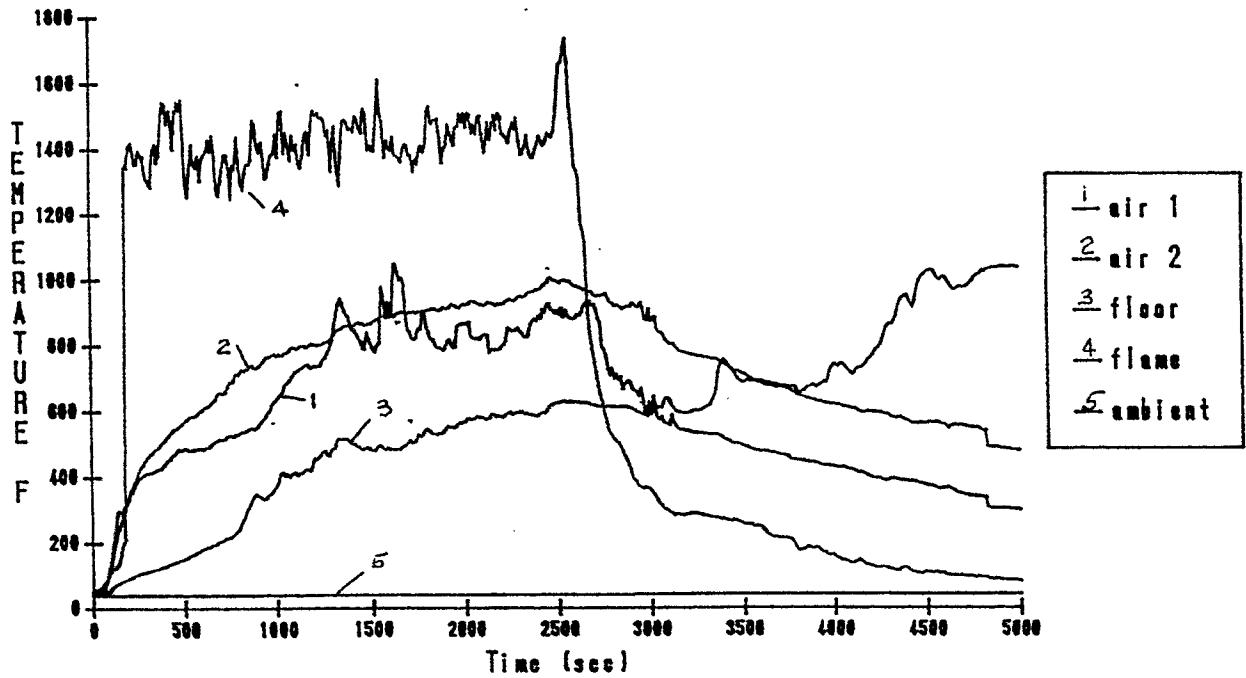




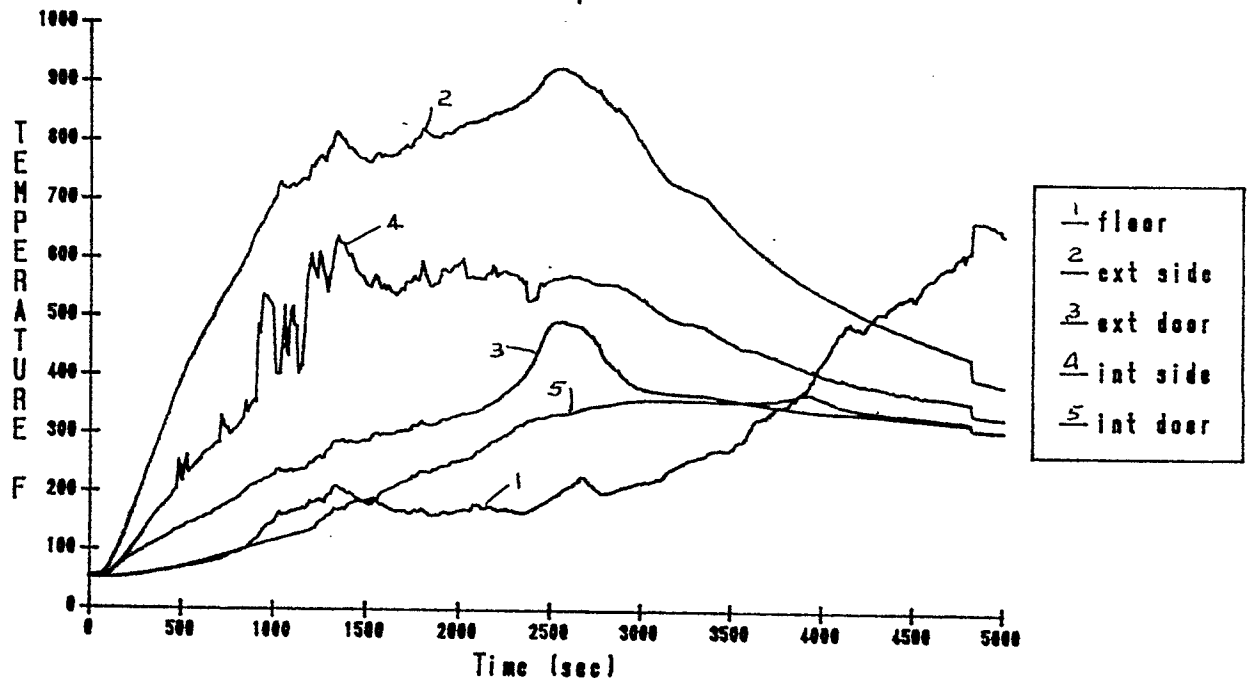


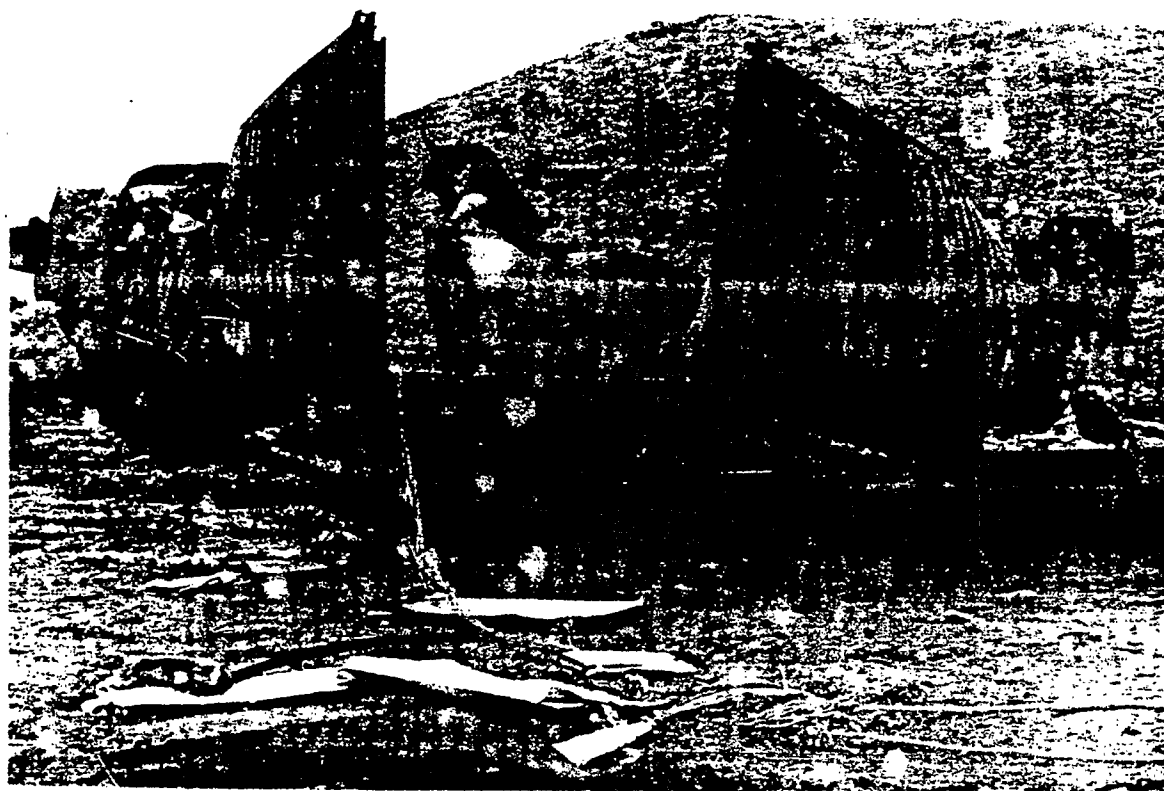


Test 1 CONEX Temperatures

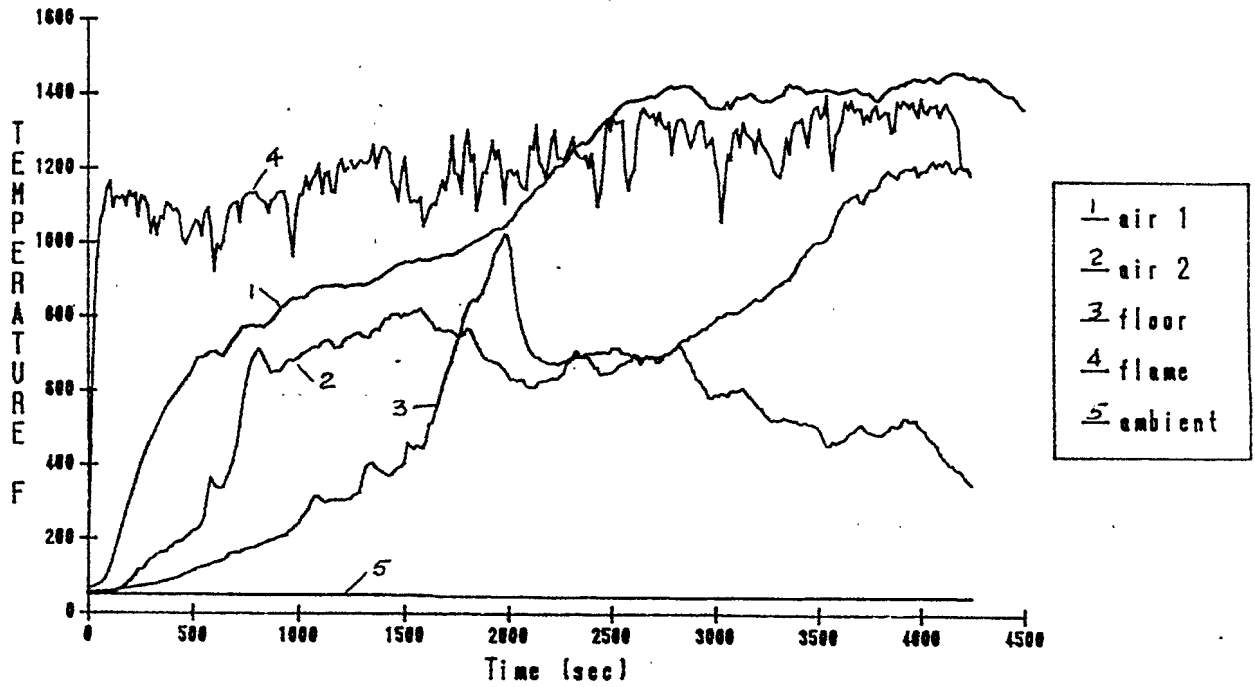


Test 1 SSC Temperatures





Test 2 CONEX Temperatures



Test 2 SSC Temperatures

